Comment on "Influence of Pair Breaking and Phase Fluctuations on Disordered High T_c Cuprate Superconductors"

In a recent Letter [1], Rullier-Albenque *et al.* studied the T_c degradation under electron irradiation of Y-123 single crystals. They have measured the in-plane resistivity $\rho_{ab}(T)$ in a broad range of defect contents x_d, the value of x_d being proportional to $\Delta\rho_{ab}$, the increase in ρ_{ab} upon irradiation. It was found that T_c unexpectedly decreased quasilinearly with x_d in the whole range from T_{c0} down to $T_c = 0$. The authors of Ref. [1] arrived at a conclusion that experimental data are at variance with Abrikosov-Gor'kov (AG) pair breaking theory [2] and point to a significant role of phase fluctuations [3] of the order parameter $\Delta(\mathbf{p})$ in high-T_c cuprates. In this Comment, we show that the data reported in Ref. [1] are in fact not inconsistent with the pair-breaking theories if (i) the deviation from pure d-wave symmetry of $\Delta(\mathbf{p})$ and (ii) the existence of magnetic scatterers in irradiated samples are properly taken into account.

The authors of Ref. [1] made use of the AG formula [2] for d-wave superconductors, $\ln(T_{c0}/T_c) = \Psi(1/2 + 1/2\pi T_c\tau) - \Psi(1/2)$, where τ is the electron scattering time, $\tau^{-1} \propto x_d \propto \Delta\rho_{ab}$. This formula gives a downward curvature of $T_c(\Delta\rho_{ab})$ curve, contrary to experimental observations [1]. Note, however, that the symmetry of $\Delta(\mathbf{p})$ in high-T_c cuprates may be different from pure d-wave [4, 5]. Besides, irradiation may result in appearance of magnetic scatterers along with nonmagnetic ones since radiation defects disturb antiferromagnetic correlations between copper spins. The AG-like formula that accounts for both those effects [6] reads $\ln(T_{c0}/T_c) = (1-\chi)\,[\Psi(1/2 + 1/2\pi T_c\tau_m) - \Psi(1/2)] + \chi\,[\Psi(1/2 + 1/4\pi T_c\tau_n + 1/4\pi T_c\tau_m) - \Psi(1/2)]$, where τ_n and τ_m are scattering times due to nonmagnetic and magnetic defects, respectively, the coefficient $\chi = 1 - \langle\Delta(\mathbf{p})\rangle^2_{FS}/\langle\Delta^2(\mathbf{p})\rangle_{FS}$ is a measure of $\Delta(\mathbf{p})$ anisotropy on the Fermi surface ($\chi = 1$ for d-wave, $0 < \chi < 1$ for mixed $(d+s)$-wave or anisotropic s-wave, $\chi = 0$ for isotropic s-wave).

An account for combined effect of both nonmagnetic and magnetic scatterers on T_c and/or an assumption about a non-pure d-wave $\Delta(\mathbf{p})$ allows for a quantitative explanation of the experimental data within the AG-like pair breaking theory, without resorting to phase fluctuations effects. Fig. 1 shows the measured T_c/T_{c0} versus $\Delta\rho_{ab}$ taken from Ref. [1] along with the curves computed for $\chi = 0.9$ and various values of the coefficient $\alpha = \tau_m^{-1}/(\tau_n^{-1} + \tau_m^{-1})$ that specifies the relative contribution to the total scattering rate from magnetic scatterers [6]. Here we make use of the relation [6] $\tau_n^{-1} + \tau_m^{-1} = (\omega_{pl}^2/4\pi)\Delta\rho_{ab}$, where ω_{pl} is a characteristic energy which should not necessarily coincide with the plasma frequency determined by, e. g., optical spectroscopy. The quasilinear dependence of T_c on $\Delta\rho_{ab}$ in $YBa_2Cu_3O_7$ is quantitatively reproduced at $\omega_{pl} = 0.75$ eV and $\alpha = 0 \div 0.01$. This value of ω_{pl} is a factor of 1.4 different from directly measured values of the plasma frequency in Y-123. Although our choice of ω_{pl} is, to some extent, arbitrary, the change in ω_{pl} will result just in the change of the best fitting values of χ and α, e. g., $\chi \approx 0.8$ and 0.6, $\alpha = 0.04 \pm 0.02$ and 0.04 ± 0.01 at $\omega_{pl} = 0.8$ and 1 eV, respectively. The data for $YBa_2Cu_3O_{6.6}$ can also be well fitted within this approach.

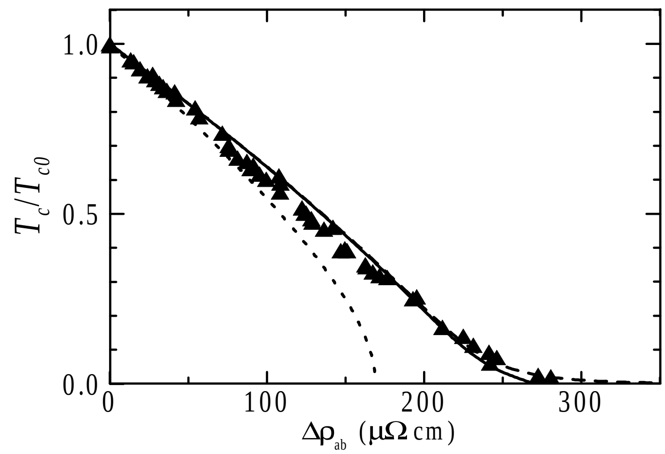

FIG. 1: T_c/T_{c0} versus $\Delta\rho_{ab}$ in electron irradiated $YBa_2Cu_3O_7$ crystals. Experiment [1] (triangles). Theory [6] for $\omega_{pl} = 0.75$ eV, $\chi = 0.9$ and $\alpha = 0$ (dashed line), 0.01 (solid line), and 1 (dotted line).

Finally, the arguments presented in Ref. [1] concerning the upward curvature of $T_c(\Delta\rho_{ab})$ curve required to explain the maximum of the transition width δT_c as a function of $\Delta\rho_{ab}$ seem to be incompatible with experimental data since the curvature of the measured $T_c(\Delta\rho_{ab})$ dependence is close to zero in the whole range of $\Delta\rho_{ab}$.

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